Scientific Inquiry

As a science teacher, you need to understand two different ways of using “inquiry” in science. First, there is scientific inquiry, which is a way of characterizing scientists’ work—what do they do and why? Second, there is inquiry science teaching which engages students in learning and using scientific practices as they develop understandings of scientific ideas and about how scientists study the natural world (National Research Council, 1996). This document introduces you to some key ideas about scientific inquiry and inquiry science teaching. It is organized around some common misunderstandings that people have about scientific inquiry and inquiry science teaching. As you read, think about which of your own ideas are being supported or challenged. What implications does this have for how you will teach science?

What is scientific inquiry?
Common misunderstanding: Scientific inquiry means using the scientific method.

From your experiences with science in school, you are probably familiar with the scientific method and its set of steps from question to hypothesis to experiment to conclusions. This is how most people learn about the scientific inquiry process. But it is a misleading and limited characterization of inquiry. Compare “the scientific method” as presented in science textbooks with the following definitions of scientific inquiry from two leading science professional groups.

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. (National Research Council, National Science Education Standards, 1996, p. 23)

Scientific inquiry is more complex than popular conceptions would have it. It is, for instance, a more subtle and demanding process than the naive idea of “making a great many careful observations and then organizing them.” It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as “the scientific method.” It is much more than just “doing experiments,” and it is not confined to laboratories. More imagination and inventiveness are involved in scientific inquiry than many people realize, yet sooner or later strict logic and empirical\(^1\) evidence must have their day. Individual investigators working alone sometimes make great discoveries, but the steady advancement of science depends on the enterprise as a whole. (American Association for the Advancement of Science, Benchmarks for Science Literacy, 1993, p. 9)

Both of these statements emphasize that scientific inquiry can be done in a variety of ways, and that there is no one scientific method. For example, while experimentation is a powerful method of gaining scientific knowledge, sometimes scientists do not do experiments at all. Scientists often use already existing observations and prior knowledge to explore questions and generate new ideas; such was the case in Watson and Crick’s work in developing the DNA double helix model (see box on page 3). In the fields of astronomy and geology, experiments are not even possible—objects of interest cannot be brought into the laboratory and put to a test that can then be replicated (Driver, Leach, Miller, Scott, 1997, p. 25). Instead, studies of the universe and paleontology and evolutionary biology base their explanations on the historical record which is studied through observations, identification of patterns, and careful interpretations. Thus, the

\(^1\) Empirical means dependent on evidence or consequences that are observable by the senses.
scientific method presents a limited view of science because there are many ways to do good science.

But a bigger problem with the scientific method view of science is that it does not capture the issues at the core of science: What is the purpose of scientific inquiry? What makes a question scientific? Why are the steps in the scientific method worth following? Read the *National Science Education Standards* (NRC, 1996) again and compare it to definition of scientific inquiry the National Research Council and from David Hammer and Emily van Zee (2006). These definitions attempt to address the core purpose of scientific inquiry:

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. (National Research Council, *National Science Education Standards*, 1996)

Inquiry asks that we think about what we know, why we know, and how we have come to know. (National Research Council, *Inquiry and the National Science Education Standards*, 2000)

Scientific inquiry, in sum, is the pursuit of mechanistic, coherent accounts of natural phenomena. (Hammer and van Zee, 2000)

All of these definitions emphasize that at its core, scientific inquiry is about developing explanations about the natural world. But it is not just about developing any old kind of explanation. These definitions suggest that explanations must be based on evidence, they must be “coherent,” and they must answer “how” and “why” questions. In addition, according to Hammer and van Zee, they must seek out mechanisms, seeking out what is causing observed phenomena.

---

STOP AND THINK. Compare the three definitions of scientific inquiry. How are they similar and different?

---

2 Mechanistic means that there is a cause-and-effect relationship. Example: “The drum sound comes to my ears because the drum vibrated and that made molecules in the air vibrate and that kept happening until it got to my eardrum.” The vibrating molecules is the mechanism (the cause) being used to explain how drum sounds get to the ears (the effect).
WATSON AND CRICK EXAMPLE: How scientific inquiry is more complex than popular conceptions would have it.

Watson and Crick did not carry out any experiments of their own to develop their explanation of the structure of DNA. Instead, they used the results from previous studies and X-ray diffraction data from Maurice Wilkins and Rosalind Franklin to help them determine DNA's molecular structure. What allowed them to develop their explanation was Crick's previous understandings about blood proteins coupled with some of their colleagues' understandings about amino acid base pair structures. Watson and Crick worked with models to develop explanations based on the evidence that others had gathered. The first models they developed, when they shared them with other scientists, were found to have flaws. With feedback from other scientists and further analysis of the evidence, Watson and Crick were able to develop an explanation that withstood scrutiny and became a commonly accepted understanding of the scientific community.

Implications for inquiry science teaching

Common misunderstandings about science inquiry teaching: The most important thing is to get students actively involved in hands-on work—they should be “doing” science.

Teachers have gotten the message that science teaching should be hands-on. And as a result, science teaching these days is much more hands-on than in the past. But the definitions of scientific inquiry from the National Science Education Standards and from Hammer & van Zee emphasize the purpose of scientific inquiry: to develop coherent, evidence-based, mechanistic explanations of the natural world. It is very common for students to be busily engaged in doing science activities—observing, measuring, drawing—without ever being involved in developing scientific explanations related to the hands-on activities. Teachers sometimes assume that the explanations will be obvious to the students, sometimes they simply tell students what the “right answer” is from an activity, and other times they simply run out of time for or fail to appreciate the importance of the explanatory work.

The definitions of scientific inquiry from the National Science Education Standards and from Hammer and van Zee suggest that the most important thing in inquiry science teaching is for students to be using evidence and reasoning to build explanations of the natural world. Hands-on “doing” is just one small part of scientific inquiry, and it is not always necessary. For example, similar to Watson and Crick, students could be thinking about and discussing their prior experiences with sinking and floating and begin building explanations about why some things float and some sink without doing any hands-on work at all. The most important part of inquiry science teaching is that students are engaged in “minds on” explanatory work.


**RACHEL EXAMPLE: Why “doing” is not the most important part of scientific inquiry.**

In Ms. Kain’s fifth-grade classroom, students germinated and measured seed plants as part of three different experiments in a six-week unit designed to develop the idea that plants are producers (they make their own food using sunlight, water, and carbon dioxide). Students were engaged in setting up the experiments, measuring the plants over time, recording results, and using a class scatter plot to average data and draw line graphs to show patterns of growth. Ms. Kain explained at one point about photosynthesis and how plants make their food, but she assumed that the doing of the experiments would lead students to discover this idea on their own. On the posttest, Rachel, like most of her classmates, had not changed her initial (incorrect) ideas that plants use sunlight and water for their food. In an interview, she explained her frustration with this plant study:

> “I don’t know why we kept measuring those plants. I mean it was fun for awhile, but I already know that plants need light and now I know it again.”

What did Rachel learn about scientific inquiry? She learned that it involves a lot of activity that does not help you make any better sense of things. She learned that science activities and processes are ends in themselves. It is important, for example, to make careful observations and to record them accurately not because such care helps you develop better understanding, but because “that’s what you do in science.” Because Rachel did not develop better conceptual understandings, the processes of science seemed meaningless and not worth the effort. Driver (1983) critiques this doing of science in the absence of meaningful conceptual development, suggesting that the “I do and I understand” slogan might more appropriately be “I do and I am even more confused.”

Common misunderstanding about science inquiry teaching: *All science lessons should be taught through inquiry.*

If students only encountered inquiry teaching in their science classes, they would not gain access to many important, useful, and interesting ideas that scientists have discovered using methods that are impossible to replicate in a typical school setting. To give students access to this knowledge requires the use of a variety of teaching approaches. Inquiry science teaching should be used in relationship to content ideas that can be effectively developed through inquiry in classroom settings. But not all science ideas can or need to be taught through inquiry investigations.

**Moving your understanding forward**

The definitions of scientific inquiry from the *National Science Education Standards*, the National Research Council, and from David Hammer and Emily van Zee are a good starting point for thinking about scientific inquiry, and they will be used throughout this module to focus your “inquiry” into inquiry science teaching.

But as suggested by the quote cited earlier (p. 1) from the American Association for the Advancement of Science, scientific inquiry is much complex than a simple definition. Instead of providing you with a comprehensive but superficial coverage of all aspects of scientific inquiry, this module will focus on six key practices that are a part of scientific inquiry. You will examine these practices in some depth as you analyze videos from science classrooms.
The six science inquiry practices are each covered in a separate document, and you will encounter them throughout the module. Each is introduced in the context of common misunderstandings, and each ends with a discussion of implications for inquiry science teaching. The inquiry practices are

1. Questions
2. Predictions
3. Explanations
4. Connections to scientific ideas
5. Knowledge growth/applications
6. Communications

PLEASE NOTE! This module is just an introduction to scientific inquiry; there is a whole field of study that examines the nature of science and scientific work. We will focus on aspects of inquiry that are most important in working with K–8 students. As you continue to learn and grow as a science teacher, you should look for ways to deepen your understanding of scientific inquiry. If you are interested in reading in more depth about scientific inquiry now, you can start by looking at the references suggested below.


References


